

**DESCRIPTION****IMPROVEMENTS IN OR RELATING TO WIRELESS TERMINALS****5 Technical Field**

The present invention relates to improvements in or relating to wireless terminals. The invention has particular, but not exclusive, application to multiple standard cellular telephones operable in accordance telephone standards such as GSM (880 to 960 MHz), DCS (1710 to 1880 MHz) and PCS 10 (1850 to 1990 MHz) and optionally Bluetooth <sup>RTM</sup> (ISM band in the region of 2.4GHz). The present invention also relates to a wireless module having an antenna and at least those components included in the coupling stages.

**15 Background Art**

In the course of developing successive generations of cellular telephones a great deal of effort has been spent on reducing the volume of the wireless terminal. Coupled with this reduction in the overall volume has been the desire to reduce the volume of the antenna whilst still maintaining its 20 sensitivity. Externally mounted monopole antennas have been succeeded by internal antennas such as PIFAs (Planar Inverted-F Antennas) and notch antennas.

United States Patent Application Publication US 2003/0103010 A1 25 discloses a handset having a dual band antenna arrangement including a PIFA. PIFAs are popular with some manufacturers of handsets because they exhibit low SAR (Specific Absorption Rate) performance (and thereby less loss to the head) and they are installed above the phone circuitry and, therefore, "re-use" the space within the phone to some degree. The PIFA disclosed in 30 this cited specification comprises a planar patch conductor mounted adjacent to, but spaced from, a ground conductor, usually a printed circuit board having at least the RF components mounted thereon. A first feed conductor is

connected to the patch conductor at a first point, a second feed conductor is connected to the patch conductor at a second point, and a ground conductor is connected to the patch conductor at a third point located between the first and second points. The impedance to which the antenna is matched can be  
5 changed by altering the relative thicknesses of the first, second and ground conductors. The PIFA is fed by a diplexer to which for example GSM and DCS circuitry is connected. In a variant the planar patch antenna has a slot which can be considered as dividing the planar conductor into two differently sized antennas connected to a common feed. The smaller of the two antennas is  
10 coupled to receive DCS frequencies and the larger of the two antennas is coupled to receive GSM frequencies. However, such antennas are physically large and are difficult to use over more than two cellular bands.

US Patent Specification No. 6,424,300 B1 discloses notch antennas for use in portable wireless terminals. The notch antenna is preferably formed in  
15 the ground plane conductor of a printed circuit board (PCB) that has RF circuitry thereon for receiving and transmitting RF signals. In this specification the notch antenna may be used as a primary antenna for radiating and receiving wireless communication signals or as a secondary antenna for receiving signals such as Bluetooth<sup>RTM</sup> or Global Positioning Signals (GPS).  
20 When the notch antenna is used as a secondary antenna, the primary antenna may comprise another notch antenna, an external monopole whip antenna or a PIFA. When the primary and secondary antennas are both notch antennas they preferably have orthogonal polarization directions which provides good isolation between them. Essentially this specification discloses a portable  
25 wireless terminal having two antennas, at least one of the two antennas being a notch antenna, for use in processing signals operating in accordance with a respective one of two standards. No arrangements are disclosed for use over more than two frequency bands

### 30 **Disclosure of Invention**

An object of the present invention is to reduce the antenna volume or increase the number of bands covered by a wireless terminal.

According to one aspect of the present invention there is provided a wireless terminal including a substrate having a ground plane, RF components mounted on the substrate and a PIFA (Planar Inverted-F Antenna) having connections electrically coupled to the ground plane, and the RF components characterised in that a notch antenna is provided in the substrate for receiving signals and in that de-activating means are provided for de-activating the notch antenna when the PIFA is being used for transmitting signals.

According to a second aspect of the present invention there is provided a wireless module comprising a substrate having RF components mounted thereon and means for connection to a PIFA (Planar Inverted-F Antenna), characterised in that a notch antenna is provided in the substrate and in that de-activating means are provided for de-activating the notch antenna.

The present invention is based on the realisation that the low SAR performance favours the use of a PIFA predominantly for transmission and a co-located notch can be used for reception (or in those applications when SAR is not considered to be important). A benefit of such an arrangement is that the antenna fractional bandwidth can be reduced if coverage of all the transmit and receive bands is divided between two or more antennas.

## **Brief Description of Drawings**

The present invention will now be described, by way of example, with reference to the accompanying drawings, wherein:

Figure 1 are illustrations of how the cellular telephone bands are allocated in the USA and in Europe,

Figure 2 is a perspective diagrammatic view of a portable wireless terminal comprising co-located PIFA and notch antenna,

Figure 3 is a Smith chart relating to the PIFA  $S_{11}$ ,

Figure 4 is a Smith chart relating to the notch antenna  $S_{11}$ ,

Figure 5 is a combined schematic circuit diagram for operating the antenna arrangement shown in Figure 2,

Figure 6 illustrates the notch antenna being terminated by a passive network, and

Figure 7 is a block schematic diagram of the PIFA and the notch antenna being operated in a diversity mode.

5 In the drawings the same reference numerals have been used to indicate corresponding features.

### Modes for Carrying Out the Invention

10 Figure 1 shows the European and North American cellular bands. The transmit bands Tx are shown in dark grey (to the left of each pair), while the receive bands Rx are shown in light grey (to the right). In Europe both the GSM and DCS bands, 880 to 960 MHz and 1710 to 1880 MHz, respectively, accommodate time division duplex systems, while the UMTS bands, 1920 to  
15 1980 MHz (transmit) and 2110 to 2170 MHz (receive), are predominantly frequency division, full duplex. In the USA, a mix of systems and duplex methods are used in the AMPS and PCS bands, 824 to 894 MHz and 1850 to 1990 MHz, respectively. The advanced wireless systems (AWS) bands, 1710 to 1755 MHz and 2110 to 2155 MHz, have recently been allocated for 3G  
20 systems, though it has yet to be resolved how the bands will be used.

Currently many phones are being made to support the European GSM and DCS bands together with the US PCS bands (in the TDMA IS54/136 mode). Since many other countries have adopted either the European or US band allocations, this allows near-worldwide roaming. To cover these bands  
25 an antenna fractional bandwidth of 15.1% is required (1710–1990MHz). To cover the transmit bands only, a fractional bandwidth of only 11% is required, that is, the required bandwidth is reduced by approximately one third. To take advantage of this, the wireless terminal in accordance with the present invention uses a PIFA or PIFAs for the transmit bands and a notch or notches  
30 for the receive bands, for example the PCS Rx band. When the PIFA is used, the notch can be de-activated by switching across its open end. Since PIFAs and notches can occupy the same volume, and both antennas are required to

cover only a sub-section of the total bandwidth, the total volume occupied can be reduced compared to other known solutions.

Figure 2 is a perspective diagrammatic view of a portable wireless terminal comprising a housing 10 containing a substrate in the form of a printed circuit board (pcb) 12, typically measuring 40x100x1mm, carrying modules and other components constituting the RF, AF and control circuits of the wireless terminal. The pcb 12 also forms a ground plane of an antenna assembly consisting of a notch antenna 14 implemented in the pcb 12 and a dual-band GSM/DCS PIFA 16 mounted above the notch antenna 14 and lying in a plane parallel to, and spaced from, the pcb 12.

The notch antenna 14 comprises a L-shaped notch N in the pcb12. The notch N comprises a first, blind ended, branch B1 extending transversely of the pcb 14. An open end of the first branch B1 communicates with one end of a second branch B2, the other end of which branch B2 opens into the edge of the pcb 12. The notch N is fed at a selected point 18 near the blind end of the first branch B1 and a tuning/switching signal is applied to a selected point 20 adjacent to the open end of the second branch B2. The notch antenna 14 may be tuned by placing a tuning capacitor 22 at the selected point 20. With a small tuning capacitor, the notch antenna 14 can be used for Bluetooth<sup>RTM</sup>, or any other frequency in the ISM band in the region of 2.4GHz (this varies from country to country), without adversely affecting the performance of the dual-band PIFA 16. With a larger tuning capacitor, the notch antenna 14 can be used for the PCS receive band (from 1930-1990MHz).

The PIFA 16 comprises a planar conductor having a meanderline slot 24 formed by a plurality of interconnected rectilinear sections L1, L2, L3 and L4. The section L1 is closed at one end and the section L4 opens into the upper edge of the planar conductor as viewed in Figure 2. The slot 24 can be considered as dividing the patch conductor into two antennas connected to a common feed, namely a smaller central radiator for the DCS/PCS frequency bands and a longer radiator, wrapped around the central radiator, for the GSM band. A feed connection 26 connects a corner 28 of the patch conductor to a connection point 30 at a corresponding corner of the pcb 12 and a ground

connection 32 connects the ground plane on the pcb 12 to a point 34 on the patch conductor located at the same side of the opening of the slot 24 as the corner 28.

In operation the notch antenna 14 may be tuned to the PCS receive  
5 band using the larger capacitor. As this frequency is close to the upper frequency at which the PIFA 16 operates, it is necessary to short circuit the notch at the open end when the PIFA is in use. This can be achieved via a simple switch SW2 (for example a PIN diode, FET or MEMs (Micro Electromagnetic Systems) device) placed at the selected point 20.

10 When the switch SW2 is on, that is conductive, the  $S_{11}$  performance of the dual-band PIFA 16 on a 40x100x1mm pcb 12 is as shown in the Smith chart illustrated in Figure 3. The Smith chart shows the simulated results for the frequencies  $f$  between 800 MHz and 3.0GHz, the source impedance being 50 $\Omega$ . The markers s1 and s2 show the GSM band edges while markers s3  
15 and s4 show the DCS band edges. It can be seen that the notch antenna 14 has no effect on the input impedance of the PIFA. The notch antenna 14 it is believed will not adversely affect the SAR.

In the simulation described above the total efficiency of the antenna (including mismatch) is greater than 60% over the GSM and DCS/PCS bands,  
20 despite the fact that the switch is assumed to have an on-resistance of just 10 $\Omega$ . Hence it is demonstrated that, in the on-condition, the switch quality is not an important factor.

With the switch SW2 off, that is non-conductive, and an optimal tuning capacitance 22 for PCS receive is applied at the open end off the notch N, the  
25  $S_{11}$  performance of the notch antenna 14 for the frequencies  $f$  between 800 MHz and 3.0GHz is as shown in Figure 4. In Figure 4, the markers s1 and s2 show the PCS Rx band edges. In making this simulation the off-state is assumed to be provided by a PIN diode with a reverse bias capacitance of 0.2pF and a Q of 20. Under such conditions a worst-case efficiency (including  
30 mismatch) of 50% is achieved. It is believed that a better performance could be achieved with the use of better quality switches, such as MEMs devices.

Figure 5 schematically represents the above described circuit model for the PIFA 16 and the notch antenna 14.

In the GSM (transmit/receive mode) and the DCS transmit mode a switch SW1, which is operated in synchronism with the switch SW2, is connected to the PIFA feed point 26. A tuning capacitor 22 shunted by the switch SW2 is connected to the notch antenna 14. The operation of the switch SW2 is controlled by a controller 36. The feed point 18 is coupled by way of a capacitor C1 to an input of a PCS receiver 38. A further capacitor C2 couples the input to ground.

The feed connection 26 of the PIFA 16 is coupled by way of a series switch SW1 to a diplexer 40. The switch SW1 is controlled by the controller 36. A GSM/DCS/PCS transmitter 42 is coupled to an input of the diplexer 40 and an output of the diplexer is coupled to a GSM/DCS receiver 44.

In a transmit/receive mode the controller 36 operates the switches SW1 and SW2 in synchronism so that both are either on or off.

In the GSM/DCS/PCS transmit modes the switches SW1 and SW2 are in their on-condition. The transmitter 42 is coupled by way of the switch SW1 to the feed point 26 of the PIFA 16. The switch SW2 in its on-condition shunts the tuning capacitor 22 thereby detuning the notch antenna 14.

When the switches SW1 and SW2 are in their off-condition then no transmit signals are supplied to the feed point 26 and the tuning capacitor 22 is coupled to the notch antenna 14 to enable it to receive PCS signals. The received signals are conducted to the PCS receiver by way of the capacitor C1.

Figure 6 illustrates the use of a passive network 46 to prevent the notch antenna 14 transmitting signals. The passive network 46 has a bandstop filter characteristic which appears as an open circuit at the frequency of the notch antenna and a short circuit at the frequency of the PIFA. For example, the PIFA 16 may be used for UMTS Tx while the notch antenna 14 is used for UMTS Rx. Since both Tx and Rx are simultaneously required for UMTS, the notch antenna 14 can be made to look inactive at the UMTS transmit frequency by the tuning capacitor and the filter, that is, the passive network 46,

being effectively short circuited and active at the UMTS receive frequency by the tuning capacitor and the filter being effective as a result of the network 46 appearing as an open circuit. The passive network may be implemented as a bulk acoustic wave (BAW) resonator.

5 More than one notch antenna may be used, for example, for the simultaneous provision of GSM/DCS/PCS and Bluetooth<sup>RTM</sup> or for the provision of diversity.

Figure 7 illustrates a simplified circuit arrangement for using the PIFA and notch antenna for switched diversity in which one or other of these  
10 antennas is selected based on signal quality/strength measurements and for simultaneous diversity in which the signals received by both antennas are combined. The outputs of both antennas are connected to inputs of respective amplifiers 48, 50. Outputs of these amplifiers are connected to a summing stage 52 which combines the outputs of the amplifiers.

15 Outputs of the amplifiers 48, 50 are also connected to a signal quality/strength measuring stage 54 which has an output coupled to the controller 36.

In the case of switched diversity the controller 36 controls the switches SW1, SW2 in the manner as described with reference to Figure 5, that is either  
20 both are in their on-condition or in their off-condition so that any one time only one or other of the PIFA or notch antenna is in use. In operation, with say the PIFA selected, a quality/strength measurement is made by the measuring stage 54. The controller 36 changes the conditions of the switches so that a measurement is made using the notch antenna 14. The results are compared  
25 and the better antenna is selected by the controller 36



In the simultaneous case, the controller controls the switches SW1, SW2 so that SW1 is in the on-condition and SW2 is in the off-condition, as shown. Signals from both the antennas are summed in the summing stage 52.

The present invention may be applied to any multi-band system  
5 where low SAR is only required for some of the bands. This is particularly appropriate for all current and future wireless communication systems.

Although the present invention has been described with reference to a wireless terminal having a PIFA antenna and operating in the GSM, DCS and PCS bands. The invention may be applied to any multiband radio and in other  
10 dual band applications.

In the present specification and claims the word "a" or "an" preceding an element does not exclude the presence of a plurality of such elements. Further, the word "comprising" does not exclude the presence of other elements or steps than those listed.

15 From reading the present disclosure, other modifications will be apparent to persons skilled in the art. Such modifications may involve other features which are already known in the design, manufacture and use of wireless terminals and component parts therefor and which may be used instead of or in addition to features already described herein.

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### **Industrial Applicability**

Antennas, wireless modules and wireless terminals such as multiple standard cellular telephones.

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